Research on Frequency Regulation Technology for Wind Power Generation

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Abstract. With the development of industrial technology, traditional energy sources are facing serious challenges, wind energy has become an alternative energy source, and its development prospects as a renewable energy source with cost-effectiveness close to traditional energy sources. However, nowadays, the enhancement of wind power FM technology is a key issue in the wind power generation system that needs to be solved urgently. This paper describes the urgency of the development of FM technology, and on this basis lists the current status of research on FM technology for wind turbine systems. The advantages and shortcomings of rotor inertia control, rotor overspeed control, pitch control, and combined control FM technology and its future outlook on wind power generation technology are introduced respectively. Separately, rotor inertia control has a high degree of instability with the possibility of a frequency drop again within a short period of time after frequency conversion. Rotor overspeed control has no hardware costs but can cause disturbances to the turbine operating speed. Pitch control is flexible and maneuverable, but can cause mechanical wear and tear. Relevant practitioners should further contribute to the power industry through advanced technical means. Offshore wind resources should be vigorously promoted and utilized. If we can make good use of it, it will bring a lot of convenience to people.

1 Introduction

With the increasing global awareness of environmental protection and the rising demand for sustainable energy, wind power, as an important renewable energy technology, has become a key component of the global energy transition. The rapid development of wind power in China has benefited from national policy support and technological advances, and has made China the country with the largest installed wind power capacity in the world. The maturity and application of wind power technology has an important role to play in reducing fossil fuel dependence and greenhouse gas emissions.

However, the widespread application of wind power technologies also faces a number of challenges, one of which is how to effectively integrate them into existing energy systems, especially in terms of frequency regulation and load management in power systems. The development of FM technologies is crucial for improving the stability and efficiency of wind power generation, especially for maintaining grid stability under highly variable wind speeds.

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At present, although a variety of frequency regulation techniques have been proposed and applied in practice, such as rotor inertia control, rotor over-speed control, pitch control, and so on. These methods still suffer from the problems of efficiency and response speed in practice.

In view of this, this review article aims to comprehensively assess the existing wind power FM technologies, analyze their advantages and disadvantages, and explore how to solve the existing problems through technological innovation. This paper hopes to provide a scientific basis and technical support for the stable operation and wide application of wind power generation in the power grid.

2 Current status of wind power generation technology and its characteristics

With the continuous development and growth of industrial technology, as well as the progress of new energy sources and the achievements made nowadays, wind power has gradually entered people's vision. Wind power in today's new energy has a certain advantage, its large scale, but also has the advantage of lower cost characteristics. So it is China's current most advantageous development of new energy, and in the forefront. According to relevant information, China's wind power generation scale is gradually expanding, the total amount of power generation is located in the world's first. Wind energy contains energy far beyond what we have seen and mastered, if people can effectively utilize wind energy as a clean energy, will bring a lot of convenience to life. Wind power can generate electricity on a large scale and without pollution, supplying power to independent users or to centralized power grids. Abundant wind energy resources, wind power generation technology is becoming more mature, wind power prices are becoming more and more competitive in the market, wind power has become the world's fastest-growing energy source. The wind power equipment manufacturing industry is developing rapidly, and various types of wind turbines, such as constant speed and variable speed turbines, have been gradually commercialized and industrialized, while large-scale wind power generation has entered the industrialization stage in various parts of the world.

Wind power generation has many characteristics [1]. First of all, as the total installed capacity continues to expand, the total amount of electricity generated as a percentage of the total increases year by year. The stand-alone capacity is expanding year by year, so the development of wind farms is gradually approaching commercialization. Even though the investment cost of wind power generation construction is high, its operation cost is relatively low [2].

Existing wind energy has the advantages of being low cost, and easy to obtain compared to other clean energy, but its equipment power generation performance is affected by many factors, such as the environment, climate, geographic location and so on can make its factors change. Therefore, in order to enhance the total installed capacity, wind power generation equipment caused by the primary power generation and frequency inertia control and other data decline in turn makes the total power generation and efficiency have a strong instability and uncontrollability characteristics. Accordingly, wind power generation now has many shortcomings, so the wind frequency conversion speed control technology is still to be studied and improved.

3 Wind power frequency regulation technology

With the depth of research, people find that there are still many ways to improve the wind power generation technology of FM technology, because the concept of wind FM is gradually

known and explored by people. Preliminary research shows that there are mainly the following methods of FM technology: rotor inertia control, rotor overspeed control, pitch control and combination control.

3.1 Rotor inertia control

Rotor inertia control, which is to control the rotor to release or absorb some of the kinetic energy stored in the rotating mass by varying the current given by the converter on the rotor side during the operation of the wind turbine in a short period of time with temporary changes. Thus to respond quickly to transient changes in system frequency, provides a rotational moment of inertia similar to that of a conventional unit. However, this method results in a significant decrease in the unit governor response, resulting in increased system recovery time and reduced capability. If it is not supported by additional power, its frequency may have the possibility of dropping again [3].

Rotor inertia control is further categorized into fixed speed type and variable speed type [4]. Fixed-speed type is commonly used in previous power generation but it has disadvantages such as small installed capacity, so it is not widely used in the future. Variable speed type has become the core equipment in today's genset, it can be very good according to the actual situation of wind energy conversion, better meet the people's demand for electricity [5]. However, in this unstable and uncontrollable situation, it is obvious that the rotor inertia control method is not a permanent solution, and the rotor overspeed control and pitch control method can effectively regulate this problem.

3.2 Rotor overspeed control

Rotor inertia control is prone to the problem of overspeed, how to make the unit rotor speed effectively controlled has become an important issue in practice. In the rotor overspeed control, the normal operation of the fan will retain a portion of the rate to prepare for the required, mainly for a time when the frequency adjustment is used. Therefore, the overspeed control mainly lies in the primary frequency in the adjustment of the response speed, the faster the speed, the smaller the impact on the fan.

The principle of rotor overspeed control is that the wind turbine can automatically release a portion of the rotor kinetic energy in response to a decrease in grid frequency and compensate for the electromagnetic power, providing a supportive and stabilizing effect. If there is a small increase in the grid frequency, the turbine can automatically retract to reduce the electromagnetic power. This frequency adjustment method is low cost because there is no hardware cost, only the need to modify the control program, and the impact on the unit's power generation is minimal [6]. The shortcomings is that there is a part of the blind zone that can not be effectively controlled, within a certain range will cause interference to the fan's operating speed, if it is beyond this range, then you need to use the pitch angle to ensure that the normal operation of the constant power.

As a result, the rotor overspeed control is also limited in its scope of application, and can only be operated within the rated wind speed. However, rotor overspeed is not limited by time but can be used most of the time, which also reduces the economic loss of wind power generation to a certain extent.

3.3 Pitch control

The principle of pitch control is to control the pitch angle in order to reduce the operating speed, so this FM method is applied in real-life windy places [7]. In this process, the unit can control the maximum operating power within the rated power range, which ensures the higher

efficiency of the operating equipment to generate more power. At the same time, pitch control can also guarantee its own power generation, so that the system can operate properly [5].

Pitch control technology in the use of wind power generation, has a strong ability to manipulate the flexibility of the adjustment range is relatively large, under any wind speed can be mediated control, can be adjusted through the pitch to ensure that the system from start to finish operation in the optimal settings, thereby improving reliability [8]. As the mechanical parts of the actuator has the disadvantage of insensitive response, so the adjustment of the pitch angle should not be too frequent, otherwise it will cause excessive wear and tear of the mechanical parts of the unit to reduce the life of the system suddenly paralyzed. However, in contrast, the advantages outweigh the disadvantages, so it is the more recommended means of frequency regulation [9].

3.4 Combined control

However, nowadays, the combination and optimization of these three common means in several frequency control means of wind power generation is the most popular at present [10]. Rotor inertia control, overspeed control and pitch control each have their own scope of application, and have their own advantages and shortcomings, the operating conditions are not consistent, if these several FM control techniques for effective improvement and regulation integration, can overcome the shortcomings, and effectively enhance the grid system power generation. Therefore, in the aspect of combination control, the relevant experts should carry out reasonable research, and constantly put the system into practice, so that it can realize high-efficiency flexible control.

A large number of related studies have been developed for the combined operation of different FM technologies. For example, some studies advocate the division of wind speed, inertia control, overspeed control and pitch implementation of the optimal combination, and ultimately supply a relatively stable and safe standby capacity to achieve the desired effect of frequency regulation. There are also studies are built on the fuzzy control coordination theory, by virtue of adjusting the pitch angle, generator torque and so on. Achieving the purpose of frequency regulation, the specific operation process is: when the wind speed is falling, the choice to change the pitch, the wind speed rises to control the given power, when the wind is equivalent, the two sides cooperate in the control, the method not only simplifies the calculation steps, but also effectively deal with the ever-changing wind speeds brought about by a variety of difficult problems [11].

4 Wind power technology development trend

4.1 Challenges faced

With the development of wind power generation technology, a large number of test results show that researchers should enhance the safety performance and stand-alone capacity of wind turbines, and vigorously apply the offshore wind resources, according to the study of the collection of offshore wind power is about 1.5 times more than on land, so it should be rationally applied, and to improve the energy storage technology [4], to ensure that wind power technology is further universalized in the same way as other energy sources.

The obstacles faced by the offshore wind power industry at this stage mainly include the following aspects. The first is the technical challenge, offshore wind power technology is more complex compared to onshore wind power, including wind turbine design, installation, operation and maintenance and other aspects of the technical difficulties are greater. At present, the offshore wind power industry in the key technology there are still some

bottlenecks, such as the design and manufacture of large wind turbines, and offshore wind power infrastructure design and construction, which restricts the development speed of the industry. Second is the cost problem, the construction and operation cost of offshore wind power projects is higher, including the cost of equipment procurement, transportation, installation, operation and maintenance. At the same time, the construction of offshore wind farms also needs to take into account the impact of the marine environment, meteorological conditions and other factors, which also increases the cost of the project. The construction of offshore wind farms also needs to take into account factors such as ecological protection, fisheries, and shipping. So the selection and planning of sites is more difficult. Finally, the lack of experience. Offshore wind power compared to onshore wind power development is relatively late, the accumulation of experience in offshore wind power is relatively small. There is also a lack of sufficient practical experience and technical reserves in project planning, design, construction, operation, and maintenance.

4.2 Vision of the future

Although offshore power generation technology has many practical factors, such as poor wind energy collection, difficulties in transmission to land, and high costs, offshore wind power generation technology has many advantages and can be developed [12]. First of all, due to the decreasing economically exploitable wind resources on land, the global wind farm construction has shown a trend of development from land to offshore. Compared with land-based wind power, the energy efficiency of offshore wind energy resources is 20% to 40% higher than that of land-based wind farms and also has the advantages of not occupying land, high wind speed, less sand and dust, a large amount of electricity, stable operation, and zero dust emission, and at the same time, it is able to reduce the wear and tear of the unit and extend the service life of wind turbines, which is suitable for large-scale development. Secondly, the sea is relatively wide, and it is very convenient to establish a large power plant site. Offshore wind speeds are more average, there is no more trouble with wind speed excursions, and the cost of controlling wind speeds is lower. Finally, the total power generation capacity of the ocean is much higher than that of the land, so we should make good use of the wind energy of the ocean so that we can better develop wind power generation technology for the benefit of mankind. It is expected that wind power generation will continue to maintain rapid growth in the future [13], and the government's supportive policies for renewable energy, the continuous progress of technology, the huge potential of the market, and the increasing emphasis on environmental protection and sustainable development will provide strong support for future development.

5 Conclusion

In conclusion, after analyzing the wind power generation frequency regulation technology, it is found that the characteristics of the frequency regulation technology determine its application status in practice. The rotor inertia control method may lead to the possibility of a further decrease in frequency for a period of time after frequency regulation. And the method of rotor overspeed control, despite the negligible cost of regulation, causes interference with the operating speed of the wind turbine. Together with pitch control, this method can regulate the frequency at any wind speed, but regulating the frequency should not be too frequent, which will cause mechanical wear and tear and damage the unit. Therefore, the combination control is proposed as a method of frequency regulation, which ultimately provides a relatively stable and safe standby capacity and achieves the desired effect of frequency regulation. Of course, offshore wind power generation should be the focus of future development. It has numerous advantages; the energy utilization efficiency of

offshore wind resources is high, the siting is convenient and suitable for large-scale construction, and the total amount of power generated by it far exceeds that of land. However, there are still many difficulties and deficiencies in today's offshore wind power technology. Many practical factors should be overcome, such as mechanical technology, cost issues, marine environment, meteorological conditions, and lack of experience. Practitioners must analyze the objective needs, make full use of the existing advantages, and research and develop application solutions that meet practical needs.

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